Title:

Development and Demonstration of a Floating Hatchery/Nursery Culture System

Applicants/Coinvestigators:

Richard C. Karney, Shellfish Biologist/Director
Martha's Vineyard Shellfish Group, Inc.
P.O. Box 1552
Oak Bluffs, MA 02557
Phone: (508) 693-0391 Fax: (508) 693-0391
e-mail MVSG@capecod.net

Jack Blake, Owner
Sweet Neck Farm
P.O. Box 1468
Edgartown, MA 02539
Phone: (508) 627-8347

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		% of Total
Requested	28,221	50%
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DEVELOPMENT AND DEMONSTRATION OF A FLOATING HATCHERY/NURSERY SHELLFISH CULTURE SYSTEM

(Picture 1A and 1B)

Summary

Under a grant from the Massachusetts Department of Food and Agriculture, Jack Blake, an Edgartown grower, constructed and operated a floating hatchery/nursery prototype. The culture system holds promise to provide a low cost and environmentally sound means of producing the shellfish seed required by the developing shellfish aquaculture industry. The floating hatchery/nursery successfully operated in three culture modes -- as a 340 gallon larval tank, as a nursery capable of handling eight downweller sieves for post-set culture, and as a nursery with eight upweller silos for rearing juveniles. The first two attempts at larval culture of quahogs failed. During the first attempt, fertilized eggs introduced to the flow through larval culture system escaped when a drain screen dislodged. A second attempt was made to culture quahog larvae. This time the larvae were cultured in a closed system tank where water was changed every other day and cultured phytoplankton was fed daily. This culture succumbed to a Vibrio infection traced to source water which was drawn from a prefilter reservoir contaminated with oyster feces from an adjacent nursery culture system. In a third attempt, two million two week old oyster larvae introduced into the system were successfully grown in a closed system mode. Within a week, the larval veligers progressed to eyed larvae and were set on microcultch in the system's downweller sieves. Juvenile oysters were eventually cultured in upweller silos in the prototype. This culture attempt resulted in over 110,000 5-20 mm oyster seed. Results from these early trials are promising. The innovative floating/hatchery is scheduled to be run again next year.

Introduction

According to the Massachusetts White Paper and Strategic Plan (September 1995), "the Massachusetts shellfish aquaculture industry is presently limited by seed availability". One of the 1997 Massachusetts Aquaculture Industry Priorities has been identified as "aquaculture demonstration projects that increase availability and demonstrate methods for reliable sourcing of... shellfish seed for cultivation within the Commonwealth." Presently, 50-70% of the shellfish seed cultured by Massachusetts growers is purchased out of state. The Massachusetts Division of Marine Fisheries (DMF) allows growers to purchase seed stock from certified hatcheries as far north as Maine and south to New Jersey. The importation of disease and questionable genetic fitness of the seed stocks from outside of this area are factors in the DMF's seed importation policy. As more growers enter the industry, the demand for dependable, disease free sources of seed shellfish will increase.

Concerns about the importation of disease and the preservation of local genetic diversity, make the development of local hatcheries the logical solution to the shortage of seed for growers. Effluent regulations and monitoring requirements, which rightly discourage large point source discharges into the marine environment, increase almost logarithmically with the size of the hatchery facility and economically discourage large operations. The ideal hatchery, then, becomes one that is not only local but also small.

In most of coastal Massachusetts, however, finding a waterfront site suitable for a hatchery, large or small, is nearly impossible. The state's large coastal population and massive coastal tourist industry create intense demands for waterfront real estate. Desirable waterfront sites for hatchery operations are either astronomically priced or zoned residential.

Jack Blake, a commercial fisherman and graduate of the Martha's Vineyard Aquaculture Training Program, designed the prototype floating hatchery/nursery shellfish culture system to supply quahog seed for Sweet Neck Farm, his new aquaculture business. Combining shellfish hatchery and on- and offshore nursery culture methods which he learned in the MVSG Aquaculture Training Program with his extraordinary talent for invention, Mr. Blake has designed a low cost floating shellfish culture system with the capacity to produce one million 1 mm seed quahogs from fertilized eggs. The floating culture system incorporates battery powered sea water and air delivery systems, water filtration capabilities, a larval culture tank, post set downweller culture units, and juvenile upweller silos.

Although tested on Martha's Vineyard, the prototype should be easily adapted to growers anywhere. Although only oyster seed was produced in this investigation, the culture system is widely adaptable for the culture of many other commercially important species.

The investigation was conducted under a contract with the Massachusetts Department of Food and Agriculture which ran from January 1, 1998 through November 20, 1998. Funding in the amount of $28,221 from the Massachusetts Department of Food and Agriculture and an in-kind match of $28,276 enabled the development and demonstration of this unique floating shellfish aquaculture system.

The culture system holds promise to provide a low cost and environmentally sound means of producing the shellfish seed required by the developing shellfish aquaculture industry. The floating design of the system eliminates the high real estate costs inherent in a land based system. The small size of the system limits the volume of the point discharge so as to have negligible impact on the marine environment. Consequently, permitting costs associated with the system are minimal. The system is compact and designed to be operated by one or two culturists. The system is visually and acoustically benign which should allow for its deployment in developed coastal areas. Further, this inexpensive small culture system can potentially provide for the local production of seed shellfish from indigenous stocks, thereby, lessening chances of the importation of disease and allowing for the production of seed genetically fit to the local environment.

Project Participants

The legal applicant for the project was the Martha's Vineyard Shellfish Group, Inc., a 501(c)(3) non-profit consortium of the shellfish departments of the towns on Martha's Vineyard. Richard C. Karney, the Shellfish Biologist/Director of MVSG administrated and provided the biological expertise in the investigation. Jack Blake, a commercial fisherman turned aquaculturist designed, constructed, and operated the prototype floating hatchery/nursery. Marcus Bradley, a hatchery assistant with the MVSG, assisted in the project.

Mr. Karney is an active member of a number of shellfish aquaculture associations, and plans to share the results of this work with other growers at such forums as the Milford Aquaculture Seminar and World Aquaculture Society, National Shellfisheries Association, and Massachusetts Aquaculture Association meetings.

List of Tasks:

a) Secure permits and insurance.
b) Purchase materials and equipment.
c) Construct of prototype.
d) Launch and complete systems shakedown.
e) Maintain back-up algal cultures.
f) Collect and spawn broodstock.

g) Operate and maintain culture systems (larvae, post-set, and juveniles).
h) Monitor environmental parameters and shellfish growth on site.
i) Transfer seed to nursery trays.
j) Haul, drain, and scrape down system.

Tasks Completed:

a) Secure permits and insurance - All necessary permits for the operation of the floating hatchery were secured. Mr. Blake possesses a local Section 57 Shellfish License and a state Section 17b Aquaculture Enterprise Permit. Mr. Blake secured permission from the Edgartown Conservation Commission for the project under Section 40, the Massachusetts Wetlands Protection Act. In addition, the project required a mooring permit from the Edgartown Harbor Master and a sign-off from the Massachusetts Department of Environmental Protection, stating that the project does not require a discharge permit in accordance with the Massachusetts Surface Water Discharge Program (314 CMR 4.00). After reviewing the locus map of the mooring location for the Floating Hatchery, Jerry Moles of the Massachusetts Division of Marine Fisheries determined that the proposed site for the project was within a DMF approved area.

Two Island insurance agents were contacted regarding a liability insurance policy for the Floating Hatchery. After much difficulty, an agent with Martha's Vineyard Insurance informed Mr. Blake that he had found a company which would insure the project. The policy went into effect on April 15, with a premium of $300.

b) Purchase materials and equipment - Materials for construction of the platform and plumbing/electrical locker were purchased and included lumber, flotation, hardware and epoxy paint. Anchor, chain and line were also purchased. Precast polyethylene tanks were purchased, including a 350 gallon larval tank, a 18 gallon holding tank for filtered water, and a 30 gallon recessed sink. Various sizes of PVC piping, valves and fittings, and flexible vinyl hoses were purchased to fabricate the plumbing systems. A number of battery operated pumps, including a 12 volt diaphragm water pump, two 12 volt submersible pumps, and a 12 amp diaphragm air pump were purchased. These pumps connected to four 6 volt deep cell batteries via marine and float switches constituted the electrical system. A 65 amp battery charger and gauge completed the electrical system purchases. From 40 feet of 18 inch PVC duct pipe and various gauges of nylon mesh, sixteen upweller and eighteen downweller silos were constructed. Stainless steel was purchased to build the support mechanism for the silos. Other purchases for the project included 5, 10, 25, and 50 micron bag filters, a compound microscope, Sedgewick-Rafter counting cells and laboratory thermometers. The complete materials and equipment cost for the project was $7,750.

c) Construct the prototype - The main platform which measures 8'x 16'x1' was constructed from plywood and fir and reinforced with welded angle iron steel work. The voids in the platform were filled with polystyrene to provide 3700 pounds of buoyancy. All exterior surfaces were painted with two coats of grey epoxy paint. A plumbing/electrical locker (2'x4'x5.5') was built on the platform which enclosed most of the electrical and plumbing apparatus and provided storage for batteries and sieves. In the floor of the platform a three bay recessed well was constructed which allowed for coarse prefiltering of the seawater with nylon prefilter bags. Internal support structures for the bags were constructed from 1/2" PVC piping. **(Picture 2)**

A support system was constructed for the polyethylene larval tank, which allowed it to be raised and lowered to facilitate trailering the hatchery, and draining and cleaning the larval tank. Stainless steel pins locked the support and tank in place. A plastic tarp with grommets was purchased and installed as a cover to protect the larval tank/downwellers/upwellers from the elements. Metal hooks attached to bungee cords held the tarp taut and in place. **(Picture 3 and 4)**

A length of 4 inch PVC pipe was modified to serve as a larval tank standpipe, a distribution manifold for downweller silos, and a support for the larval tank cover. The standpipe was designed to be adaptable to accept two filters to prevent larvae from escaping when the larval system is run in a flow through mode. The manifold was constructed from PVC with eight outlets to supply eight downweller culture units. Sixteen downweller units were built from 18 inch PVC duct pipe (eight with 130µ mesh, eight with 300µ mesh).

The larval tank was designed to be converted for upweller use by the substitution of a 12 inch standpipe with eight outlet ports for the 4 inch stand pipe used during the larval culture period. Sixteen upweller silos were constructed from 18 inch PVC duct pipe and 400 and 600µ nylon mesh. The downwellers and upwellers are supported in the larval tank via an octopus array of eight stainless steel support arms. **(Picture 5)**

A support structure was built for a recessed polyethylene sink which served as both a reservoir to pump coarse filtered water to the bag filters, and, when pumped dry, provided a space below water level to facilitate gravity drain down of the larval tank. **(Picture 6)**

Bulkhead fittings were installed in the tanks and sink, and the entire system was plumbed with PVC piping. The plumbing system provided for bag filtering seawater to 5 microns. A series of pumps under the control of float switches was wired to the batteries and provided a water pumping capacity of up to 25,000 gallons in a 24 hour period. A battery operated air pump was wired and provided aeration.

Four plastic bag filter adapters were installed above an 18 gallon holding tank. This arrangement allowed water pumped from the recessed sink to pass through removable bag filters prior to its addition to the larval tank and/or downwellers. A submersible pump in the holding tank provided for the transfer of water to the larval tank. A 12 volt diaphragm pump, capable of pumping 3 gallons per minute at 60 pounds pressure, pulled water from the holding tank and provided a source of filtered water for rinsing. **(Picture 7,8, and 9)**

In addition to the sixteen upweller silos and sixteen downweller sieves, Mr. Blake constructed seven interlocking sieves for sizing the shellfish from 12 inch schedule 120 PVC with nylon mesh between 35µ and 300µ . **(Picture 10)**

d) Launch and complete systems shakedown - On June 19th Jack Blake launched the completed hatchery prototype from Collins Beach in Edgartown. The floating hatchery was towed to the mooring site outside Caleb's Pond in Katama Bay. The floating hatchery was shackled to Mr. Blake's new tidal upweller shellfish nursery. **(Picture 11A, 11B, and 12)**

The systems shakedown was begun. The systems were run for several days at an operating flow of 1,000 gallons per hour to season the system, and evaluate power usage, filter bag clogging and general operation. Mr. Blake was happy to report that the bank of batteries appeared to not need daily charging except when operating the 12 amp air pump. Operation of the air pump necessitated a daily change of the batteries. With all electrical water pumps operating, the batteries provided electricity to the system for three days. There were some minor problems with slippage of filter bags on the incoming source water and some problems with the mesh on the larval tank standpipe clogging with silt. Minor adjustments to both the filter bags and increasing the mesh size on the larval tank overflow screen appeared to have rectified the situation. Mr. Blake spent another two weeks fine tuning the mechanical systems before introducing fertilized eggs to the system. The unusually rainy and stormy weather delayed the launch which was originally scheduled for the first week in June. Water temperatures were depressed resulting in our rescheduling the introduction of shellfish embryos to the system from early July to the middle of the month. **(Picture 13 and 14)**

e) Maintain back-up algal cultures - Various cultures of phytoplankton were maintained in the MVSG hatchery throughout the project period. Plans were to add the algae if the flow through system failed to supply adequate natural phytoplankton for good nutrition of the developing shellfish larvae. When it became necessary to grow the larvae in a static system, these cultured algae were provided as food for the shellfish larvae . The stock cultures included Tahitian strains of Isochrisis, three Tetraselmis species, two Chaetoceros species, one species of Rhodomonas, and the diatom Thalassiosira weissfloggi. The larvae cultured in the floating hatchery system were fed with cultures of Isochrisis galbana (Tahitian strain, T-ISO), Chaetoceros neogracili (Chaet B), and Tetraselmis chuii. **(Picture 15A and 15B)**

f) Collect and spawn broodstock - Mr. Blake collected quahog broodstock from Caleb's Pond in Edgartown on July 14. The broodstock were brushed in fresh water and left at room temperature overnight in preparation for the spawning on July 15. The quahogs were distributed in Pyrex dishes filled with 5 micron filtered seawater and subjected to thermal stimuli to induce spawning. The obviously ripe animals readily spawned. Within several hours, eleven females and twenty-six males produced almost 29 million fertilized eggs. Five males were wild stock. All the rest of the spawning broodstock were notata. **(Picture 16)**

Following the loss of the larvae from the first spawn, an attempt was made to spawn quahogs again on July 21. This spawning attempt failed in that not enough eggs were released. We suspect the broodstock used were already spent.

A third attempt to spawn the quahogs on July 23 was successful with eight males fertilizing 15 million eggs from eight females.

The quahog larvae in the second culture trial were lost to Vibrio bacterial contamination. Rather than attempt another quahog spawning so late in the season, the third larval culture trial utilized surplus oyster larvae from an oyster spawning conducted on July 16. Two and a quarter million fourteen day old oyster larvae culls were introduced to the floating hatchery larval tank on July 30. These larvae represented a slow growing component of the July 16 spawning and although they were large enough to be caught on a 130 micron sieve, they were too small to be caught on a 160 micron mesh.

g) Operate and maintain culture systems (larvae, post-set, and juveniles) - The floating hatchery/nursery was capable of operating in three culture modes -- as a 340 gallon larval tank, as a nursery capable of handling eight 18" diameter by 7" deep downwellers for post-set culture, and as a nursery with eight 18" diameter by 14 1/2" deep upweller silos for rearing juveniles.

Ambient seawater entered the system through an opening in the bottom of the raft platform that is 3" by 12", and is three feet up current from the discharge pipe. The water passed through a series of bags in prefilter raceways recessed in the floor of the platform. Nytex screens of 200, 400, 300 and 800 microns were fitted into the intake raceway to prefilter all seawater entering a sink. From this prefilter box, the coarse filtered water flowed to the sink via a 2" PVC pipe controlled with a gate valve. The gate valve at the bottom of the sink allowed for the control of how much water passed through the system on a daily basis.

When the water level in the recessed sink is about 2" below sea level (nearly full), a float switch turns on a submersible pump in the bottom of the sink and pushes the water up an extra 5 1/2' so as to spill into filter bags hanging over an 18 gallon open holding tank. Water passes through filter bags of 5 to 50 µ (depending upon the size of the animals being fed) and into the holding tank. An overflow pipe from the holding tank allows the filtered water to spill into the larval tank. A 2" ball valve on this line may be shut when changing the bag filters, in order to prevent contamination of the larval tank. The filtered water flows into a manifold with eight outlets each of which has 2-3' of vinyl hose attached. The filtered water dropping from these hoses provides aeration and water movement within the larval tank. Water exits the larval tank through a standpipe whose outlet is covered with 100 square inches of filter mesh (44-51µ depending on the size of larvae). **(Picture 17)**

In the original design, the standpipe was connected to the sink with a 1 1/2" flexible hose. This drain hose passed through the sink and connected to a 1 1/2" ball valve located downstream from a 1" barb fitted with 1' of vinyl hose with a spigot at the end. In flow through operating mode, the drain ball valve in the sink is opened and water discharges through a bulkhead fitting 2" below sea level. To drain the larval tank and contain the larvae, the valve is shut, the spigot opened, and the larvae caught on an appropriately sized sieve.

In the course of the operation of the floating shellfish hatchery/nursery prototype, Jack Blake corrected flaws in his culture systems. Changes were made in both pre-filters and drain filters. The larval tank standpipe was redesigned to allow the use of a siphon hose rather than the bottom hose for draining the larval tank. Modifications were made to better secure siphon hoses and drain sieves to accomodate the instability of an open water hatchery system.

Throughout the culture period, the system was checked daily. Intake screens were cleared, filter bags cleaned, and batteries exchanged and recharged as necessary. Every second day during the larval culture, the larval tank was drained, cleaned, and refilled. At these times, the larvae were sieved, examined, and culled. **(Picture 18 and 19)**

First Trial

About 20 million fertilized eggs from the July 15 spawning were transferred in seawater in Nalgene carboys and introduced into the larval tank of the floating hatchery. The larval tank was set up as a flow through system and covered. The tank received approximately 166 gallons per hour of 5 micron bag filtered seawater from Katama Bay at 23.4 C and 29 ppm salinity. The temperature of the seawater in the larval tank was measured at 24 C. On July 16, the larval tank was checked and it was found that both 40 micron filter bags on the larval tank standpipe had worked their way off sometime during the night. Mr. Blake plugged both of the holes, aerated the tank, and went home to get two 51 micron filters which were rigged to the larval tank. The flow of seawater through the larval tank was resumed. On July 17, both 51 micron filters were observed to be clogged and the tank was overflowing. The water in the tank was drained down through a 35 micron sieve which collected the remaining larvae. A sample was counted, which resulted in an estimate of only about a half million larvae left in the tank. It was obvious the larvae had escaped both when the filter bags worked free and when the tank overflowed. A decision was made to release the rest of the larvae, clean the hatchery, and spawn again. Materials were ordered to build larger mesh filter bags secured in such a way that they would not work free during the sloshing inherent in the operation of a floating field hatchery. **(Picture 20 and 21)**

Second Trial

A decision was made to culture the second group of eggs spawned on July 23 in a closed larval tank system rather than flow through. Despite the fabrication of new filters, we were not confident enough to risk losing the larvae again. We were afraid we were at the end of the spawning season and may not be successful in locating ripe quahogs to spawn again.

On July 23, 15 million fertilized eggs were introduced into 5 micron filtered, aerated seawater in the floating hatchery larval tank. The larval tank was filled about two-thirds full (220 gallons) to allow for sloshing. The temperature in the tank was measured at 24.5 C. On July 24, 4 liters of phytoplankton (T-ISO) were fed to the culture. Continuous operation of the air pump necessitated changing the batteries on a daily basis. On July 25, the larval tank was drained through a 35 micron sieve. A sample of the larvae retained on the sieve gave an estimate of 2.5 million alive. However, the state of their health was questionable. The tank was cleaned, refilled with 5 micron seawater (24.5 C) and fed about 3.5 liters of T-ISO. On July 26, a 1 ml sample taken directly from the tank revealed 3 larvae. As there were approximately 800 liters in the tank, a count of 2.5 million was estimated. Some settling was observed on the bottom of the larval tank. The water temperature in the tank was measured at 25 C. Two liters of T-ISO were added. On July 27, the culture was drained for the second time. The count revealed larvae mostly dead or dying with deformed velums, an indication of vibriosis. With only a quarter million healthy animals remaining, a decision was made to discard the culture, try to determine the source of the Vibrio bacteria, and start again. **(Picture 22, 23, and 24)**

A major cleaning of the system was carried out. Fouling and silt were found trapped in the flexible pipe draining the larval tank into the sink. More importantly, Mr. Blake discovered large amounts of silt in the recessed prefilter raceway. Upon reflection, Mr. Blake realized that his practice of rinsing the juvenile shellfish from his abutting tidal nursery atop the cover of the prefilter box resulted in fecal contamination of the incoming seawater flow to the larval tank. We suspect this practice was the major source responsible for introducing vibrio bacteria to the culture. Attempts were subsequently made to change the identified bad housekeeping practices. The system was thoroughly cleaned and all possible contaminated surfaces were wiped with a chlorine solution. Additionally, a decision was made to soak the filter bags in a chlorine solution between use. **(Picture 25 and 26)**

Third Trial

The third larval culture trial utilized two week old oyster larvae runts culled from an MVSG hatchery culture spawned on July 16. About 2.25 million larvae (>130 microns, <160 microns) were introduced into the larval tank of the floating hatchery on July 30. The seawater in the tank was aerated, filtered to 5 microns, 24.9 C, with a salinity of 31.3 ppt. The larvae were fed with 10 liters of cultured phytoplankton (T-ISO, T.Chuii, and Chaet B). On July 31, 12 liters of the same mix of cultured phytoplankton were fed.

On August 1, the tank was drained down using a siphon hose to bypass the contamination suspected in the bottom drain hose. Samples of the oysters appeared to be in good health and grew so that the majority now were caught on a 183 micron sieve. The larval tank was cleaned, refilled with 5 micron bag filtered seawater at 23 C. The oyster larvae and 12 liters of cultured phytoplankton were added. On August 2, 15 liters of the cultured phytoplankton mix were fed.

On August 3, the tank was drained again. The collected larvae were sized, counted, and those caught on a 209 micron sieve were observed to be eyed and ready to set. These were concentrated on nylon mesh, wrapped in damp paper towel, and refrigerated overnight. These were introduced into downweller sieves for setting the following day. We estimated the count on the 209 micron mesh at 930,000. The larvae that passed through the 209 micron mesh (about one million) were resuspended in clean filtered seawater in the tank and fed 20 liters of cultured algae. Water temperature was measured at 24 C. **(Picture 27 and 28)**

On August 4, the contents of the larval tank were again siphoned and most of the larvae grew enough to be caught on the 209 micron mesh and were ready to set. As the larvae became competent to set, they were placed on downweller sieves fitted with 130μ Nytex. Water enters and exits the larval tank in the downweller mode in the same manner as it does in the flow through larval culture mode, except that the input hoses flow into the downwellers. The tank was cleaned, filled with 5 micron seawater, fed 22 liters of cultured algae and set up to accept eight 18" diameter downwellers (130 micron mesh) to which crushed oyster shell cultch(1-2 mm) was added. The pump was set to deliver a flow of about 140 gallons per hour of seawater filtered to 5 microns. Ambient water was measured at 24 C. About 1.7 million eyed oyster larvae were equally distributed in the eight downweller sieves. **(Picture 29 and 30)**

The system was observed on August 5, at which time, the pump was moving about 3700 gallons per day through the system. The water temperature was measured at 25.5 C. The larvae were observed to be swimming and healthy. The oyster chip cultch in the downwellers was collecting at one end, covering about one fifth of the bottom area.

On August 6, the filter bags were changed and the water flow increased to 5700 gallons per day. Many oysters were observed setting on the sides of the downwellers. Water temperature was 25 C. By August 8, few oysters were observed swimming and it appeared that a large number had set on the chips in the downwellers. On August 10, oysters that set on the sides of the downwellers were gently removed with a brush and transferred to one of the downwellers. Survival of the brushed oysters was estimated to be 50% and about 20% had grown large enough to be caught on a 300 micron mesh sieve.

By August 11, seawater flow through the system was increased to 12,000 gallons per day. It was observed that four 5 micron bags had clogged three quarters of their capacity in 2 days. On August 13, bag filter size was increased to 10 microns.

On August 17, the downweller sieves (130 micron) were observed to be overflowing. They were cleaned and the oyster chip was rinsed. The single oysters appeared to be growing well and were estimated to be about 400-500 microns in length. The batteries, which were last changed on August 13, were still in a charged state, but couldn't last another day. Mr. Blake determined that he could pump 25,000 gallons at 7' head per charge using two 1500 gph Rule pumps.

On August 21, large chip cultch with attached oysters was moved from the 130 micron downweller sieves to 400 micron mesh upwellers. In the upweller mode, a different standpipe is used. The system allows both upwellers and downwellers to operate simultaneously, with some water passing through the downwellers before exiting through the upwellers.

On August 25 with Hurricane Bonnie threatening, the oyster seed was microscopically examined. The oysters brushed from the sides of the downwellers on August 10 were found to be heavily fouled and had suffered high mortality. Oysters set on the smallest chip cultch exhibited the best survival. The first of the large chip oysters were moved to the tidal upweller and the remaining oysters thinned. The oyster seed continued to be tended in the hatchery downweller and upweller units until September 11, when the last of the seed was transferred to the tidal upweller nursery, and the hatchery pumps were shut off.

h) Monitor environmental parameters and shellfish growth on site - Culture records including temperatures, flow rates, volumes of supplemental phytoplankton, and the growth and survival of the shellfish was kept for the duration of the project. Ambient seawater temperatures have been recorded almost daily since the launch on June 19. Assistant Marcus Bradley was trained in the use of a Horiba multimeter probe. Measurements of seven environmental parameters at the culture site were recorded during the month of July. Ambient seawater temperature, salinity, conductivity, turbidity, dissolved oxygen and pH were measured using the Horiba probe. Fluctuations in natural phytoplankton assemblages are so variable that a reliable measurement of the available natural phytoplankton was determined to be outside of the scope of this project. Secchi disk readings from the site provide a rough but adequate estimate of the productivity of the water at the culture site for the purposes of the project. The environmental data is presented in the attached graph and table.

i) Transfer seed to nursery trays - On August 25, the first of the juvenile oysters were moved from an upweller unit of the floating hatchery to a 740 micron mesh tray in Mr. Blake's adjacent tidal upweller. By September 11, the last of the seed was transferred to the tidal upweller nursery at which time the floating hatchery pumps were turned off. By the end of the project period, November 11, the production from the third culture trial was estimated at over 110,000 5-20 mm oyster seed. **(Picture 31 and 32)**

j) Haul, drain, and scrape down system - On October 13, the floating hatchery/nursery was hauled from the water, biofouling was scraped from the unit, and it was trailered to Jack Blake's yard. On October 14, the floating hatchery/nursery was powerwashed. All eight batteries were set on a float charge in Mr. Blake's shop in preparation for another production cycle in 1999. **(Picture 33 and 34)**